MICROSOFT™ TASC™

The Applesoft* Compiler

MICROSOFT™
TASC™ User's Manual

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SYSTEM REQUIREMENTS

TASC™ requires an Apple II Plus® or an Apple II® with the Applesoft firmware card installed, 48K RAM and a minimum of one disk drive. TASC supports but does not require the Microsoft RAMCard™ or Apple Language System.

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1. Introduction

Microsoft's TASC™ is designed to complement the Applesoft™ interpreter, to extend the Applesoft language, and to enhance execution of Applesoft programs. The Applesoft interpreter itself was designed by Microsoft, Inc. and later modified by Apple Computer, Inc. The interpreter/compiler combination is the ideal Applesoft program development tool since programs can be quickly entered and debugged with the interpreter, then optimized for speed with the compiler.

The compiler supports the Applesoft language with only a few exceptions. Therefore most of the programs already written in Applesoft for the Apple II can be compiled with little or no change.

Other major benefits provided by TASC are:

1. Increased execution speed

   Applesoft programs compiled with TASC normally run from two to twenty times faster than the same programs run under the interpreter.

2. Inter-program communication

   Programs can be made to communicate with each other with the use of COMMON variables.

3. True integer arithmetic

   Unlike the Applesoft interpreter, TASC can perform true integer arithmetic. Integer arithmetic can greatly increase execution speed.

4. Source-code security

   TASC creates machine language equivalents of Applesoft BASIC programs. This machine language file is all that

need be distributed when a commercial application is sold. Therefore, the Applesoft program, (called a "source" program) is protected from copy or plagiarism.

5. Disk-based compilation

   Unlike other Applesoft compilers that create the machine language version of the program in memory, TASC writes out the machine language program to disk as it compiles. This allows TASC to compile programs of virtually any size.

These benefits are important for speed-critical applications such as graphics, and for applications in which a large system of programs needs to be supported by a main menu. TASC is also outstanding for commercial applications sold in a competitive marketplace that require source-code security.

TASC is particularly good for programs that are otherwise too large to fit in memory. By separating such programs into parts and communicating between them with COMMON variables, large systems of communicating programs can be created. TASC is an example of such a large system, since TASC was separated into parts and used to compile itself. This gives an indication of the impressive power of TASC as a programming tool.

1.1 How to Use this Manual

The first three chapters of the TASC User's Manual are designed for users who are unfamiliar with the compiler as a programming tool. Following chapters give a thorough technical description of TASC and its use. Therefore, at first this manual serves as an introduction to TASC and the compilation process; later the manual serves as a technical reference. With this structure in mind, this manual is organized as follows:

Chapter 1, Introduction — Provides brief descriptions of the contents of the TASC package, and gives a list of resources for learning Applesoft programming.

Chapter 2, Demonstration Run — Explains the compilation and execution of a demonstration program.

Chapter 3, Introduction To Compilation — Gives an introduction to the vocabulary associated with compilers, a comparison of interpretation and compilation, and an overview of program development with the compiler.

Chapter 4, Debugging With The Interpreter — Describes how to debug the source file with the Applesoft interpreter before compiling the same source. Chapter 7, A Compiler/Interpreter Language Comparison, describes differences between TASC and the Applesoft interpreter.

Chapter 5, Compilation — Describes the use of TASC in detail, including the various compiler options.

Chapter 6, Executing A Compiled Program — Describes how to run a compiled object file.

Chapter 7, A Compiler/Interpreter Language Comparison — Describes all of the language, operational, and other differences between TASC and the Applesoft interpreter. This chapter should be read before attempting to compile any programs with TASC.

Chapter 8, Language Enhancements — Describes TASC's extensions to Applesoft.

Chapter 9, How The Compiler Works — Describes the inner workings of the compiler.

Chapter 10, Error Messages and Debugging — Describes each error message and discusses common problems.

Appendices include:

A. Moving Binary Files with the ADR Utility — How to BLOAD and BSAVE binary files with the ADR utility
B. Copying TASC and Converting to DOS 3.3 — How to copy and convert the TASC compiler
C. Creating a Turnkey Disk — How to create a turnkey disk for compiled programs
D. Notes on Applesoft — Information on unusual Applesoft features
E. Runtime Memory Map — Memory usage by compiled programs
F. Zero Page Usage — Zero page locations used by compiled programs

This manual assumes that the user has a working knowledge of the Applesoft language. For additional information on Applesoft programming, refer to Section 1.3, Resources for Learning Applesoft.

1.2 Contents of the TASC Package

The TASC package includes this manual and one diskette containing the following files:

1. TASC — The Applesoft Compiler
2. PASS0, PASS1, PASS2 — Internal components of TASC
3. RUNTIME — Library of machine language routines used by compiled programs
4. ADR — Utility for binary files
5. CREATE ADR — Utility for creating ADR on other disks
6. BALL — Demonstration program

IMPORTANT

> Language, operational, and other differences between TASC and the Applesoft interpreter are described in Chapter 7, A Compiler/Interpreter Language Comparison. These differences should be read before attempting to compile any programs with TASC.

1.3 Resources for Learning Applesoft

Microsoft provides complete instructions for using TASC. However, this manual does not provide any tutorial material for learning Applesoft. The following texts are good sources for this information:

1. Apple Computer, Inc. *Applesoft II BASIC Programming Reference Manual*, 1978.

2. Apple Computer, Inc. *The Applesoft Tutorial*, 1979.

3. Albrecht, Robert L., LeRoy Finkel, and Jerry Brown. *BASIC*. John Wiley & Sons, 1973.

4. Coan, James S. *Basic BASIC*. Hayden, 1970.

5. Dwyer, Thomas A. and Margot Critchfield. *BASIC and the Personal Computer*. Addison-Wesley, 1978.

2. Demonstration Run

IMPORTANT

> Before beginning this demonstration run, make a backup copy of the TASC disk. Store the master disk in a safe place and work with the backup copy. If you are using a system with DOS 3.3, you need to transfer your files to a 16-sector disk with the DOS 3.3 MUFFIN program. This procedure is discussed in Appendix B, Copying TASC and Converting to DOS 3.3.

This chapter provides step by step instructions for using TASC. We strongly recommend that you perform the demonstration run **before** compiling any other programs, since the demonstration run gives you a working overview of the compilation process. If you enter commands exactly as described in this chapter, you should have a successful session with TASC.

TASC is simple to use. To invoke the compiler, first boot up your disk and then type:

```
] RUN TASC
```

Note that your input is in bold-face type. Next, answers to a few simple questions are required to begin the actual compilation process. The first two prompts ask you for the names of the source and object files:

```
SOURCE FILE?  BALL

OBJECT CODE FILE:
(DEFAULT BALL.OBJ)?  <RETURN>
```

The source file is an Applesoft program named BALL that already exists on disk. The object file is the machine language binary file that is created by the compiler. The object file name defaults to the original file name with the extension .OBJ added, so that the object file produced for the BALL program is BALL.OBJ. The default is specified by entering <RETURN>.

The source file is assumed to be located on the same disk as the compiler unless you specify otherwise. The object file defaults to the same disk that the source is on. Different slots or drives can be specified using the normal ,S<slotnumber> and ,D<drivenumber> syntax. Compilation is usually slightly faster if only one drive is used. Disk commands can be executed by typing <CTRL-D> followed by the command and <RETURN>.

The next two prompts ask you whether you want default values for all other compilation options. Since most compilations are performed with the same set of options, you should enter <RETURN> after each prompt to specify the default values:

```
MEMORY USAGE:
DEFAULT CONFIGURATION? <RETURN>

OPTIONS:
DEFAULT CONFIGURATION? <RETURN>
```

If you had refused the default configurations above, you would need to explicitly specify the values of several compilation options. These options are explained in Chapter 5, Compilation. The actual compilation process starts without further input since you have specified the defaults above.

When compilation begins, the disk is accessed almost constantly to either read the source file or to write the object file. The compiler lists the source program on your console as it is being compiled, and generates appropriate messages if it encounters any errors. When the source stops listing, the first part of compilation is finished, and the compiler prints:

```
*****BEGINNING PASS2
```

The second part of compilation also uses the disk extensively. To indicate that it is still compiling, the compiler prints a period on the screen every few seconds. When it is finished, the compiler prints:

```
*****CODE GENERATION COMPLETE
```

At this point, the actual compilation process is complete. So that you will receive a listing of compilation information, answer "Y" or "YES" to the next prompt:

```
COMPILATION INFORMATION AND LINE NUMBER
REFERENCE TABLE? YES
```

This input also accepts <CTRL-D> disk commands. If you want to list the compilation information on a printer, you can first turn on your printer by entering:

```
<CTRL-D> PR#<printerslot>
```

TASC prints out the desired information, displays the following message, and then re-enters the interpreter:

```
*****COMPILATION COMPLETE

]
```

The increase in the BALL program's execution speed is quite apparent when compared to the same program running under the interpreter. Compare speeds by first running the interpreted program:

```
]RUN BALL
```

Next, execute the compiled program by entering the following DOS commands:

```
]BLOAD RUNTIME
]BRUN BALL.OBJ
```

Note that the RUNTIME library must be BLOADed in memory before BALL.OBJ can be BRUN.

You have now successfully completed the demonstration run. Be sure to read Chapter 7, A Compiler/Interpreter Language Comparison, before attempting to compile other Applesoft programs.

3. Introduction to Compilation

This chapter introduces the vocabulary of compilation, compares compilation to interpretation, and describes the program development process used for developing compiled Applesoft programs. These three topics serve as an introduction to compilation.

3.1 Vocabulary

Although this manual attempts to keep technical language to a minimum, the following terms must be understood:

Source File — The Applesoft program is commonly called a source file because it is the source from which an equivalent machine language file is created. The source file is the input file to the compiler. CATALOG lists the names of Applesoft source files with the letter "A" preceding the size of each file.

Object File — TASC translates source files into machine language object files. The object file is the output file created by the compiler. The object file is an executable binary file that is the machine-language equivalent of the source. CATALOG lists the names of TASC object files with the letter "B" preceding the size of the file.

Compiletime — The time during which the compiler is translating a source file into an object file.

Runtime — The time during which a compiled program is executing. By convention, runtime refers to the execution time of a compiled program, and not to the execution time of the compiler.

Runtime Library — A collection of machine language routines that are used by compiled object programs. These routines all reside in the file named RUNTIME. RUNTIME must be loaded into memory before an object file can be executed.

3.2 Compilation vs. Interpretation

Since the microprocessor in the Apple can execute only its own machine instructions, it does not execute Applesoft program statements directly. Instead, statements must be simulated by machine

language routines that perform the operations specified by each BASIC statement.

Compilers and interpreters provide two different methods of approaching this translation problem. This difference in method is demonstrated in the following analogy:

An Analogy

Suppose you wish to build a stereo from a kit. Unfortunately, you find that the provided instructions are written in Japanese, a language that you do not know.

One way of approaching this problem is to use a Japanese-English dictionary to translate and perform each instruction one by one. This process parallels the interpretation of Applesoft statements by the Applesoft interpreter. Your construction of a stereo kit is analogous to the Apple's execution of a program.

Inefficiencies can arise in this process, especially if you fail to write down the translated instructions as they are carried out. Suppose, for example, that halfway through the construction process you translate an instruction that says:

> Go back to instruction fourteen. Then repeat the preceding steps for the second speaker.

One problem becomes immediately apparent: you can't even find instruction fourteen without scanning the instructions from the start for the Japanese characters for fourteen. You then face the time-consuming task of re-translating each instruction so that the second speaker can be assembled precisely like the first; likewise, the Applesoft interpreter must repeatedly translate each statement executed inside a FOR/NEXT loop.

A faster, alternative approach to constructing the stereo is to sit down at a table with pencil and paper, away from the stereo kit, and translate the entire instruction sheet into English. When you are done, you have a new set of instructions written in English. These English instructions correspond to the object file created by TASC.

The actual assembly of the kit can then proceed without any further translation, and even without any further need for the original Japanese text. When you finally sit down to build your speakers, you construct them very quickly. Similarly, a compiled BASIC program does not require the original BASIC source and runs very quickly in comparison to the interpreted version of the same program.

This analogy gives you a feel for the difference between interpretation and compilation. The following paragraphs discuss interpretation and compilation more technically, but also more directly.

Interpretation

The interpreter translates Applesoft source statements line by line at runtime. Each time the interpreter executes an Applesoft statement, it must analyze the statement, check for errors, and call machine language routines that perform the desired function.

When statements must be executed repeatedly, as must those within a FOR/NEXT loop, the translation process must be repeated each time the statement is executed.

In addition, BASIC line numbers are stored in a list. GOTOs and GOSUBs force the interpreter to search this list to find the desired line. This search is quite slow when the needed line is near the end of a long program.

The interpreter keeps track of variables using a list, too. When it encounters a reference to a variable, the interpreter searches from the beginning of the list to find the desired variable. If the variable is not present in the list, the interpreter must create a new entry for it. This procedure also slows interpreted programs.

Compilation

A compiler, on the other hand, takes a source program and translates it into a machine-language object file. This object file consists of a large number of machine language CALLs to routines in the runtime library and to routines in the Applesoft interpreter. By calling routines in the Applesoft interpreter, TASC assures close language compatibility with the interpreter.

In contrast to the interpreter, the compiler analyzes all statements **before** runtime. In addition, absolute memory addresses are provided for variables and program lines. These addresses eliminate the list searching that occurs while an interpreted program executes.

TASC, unlike the interpreter, implements true integer arithmetic and integer loop variables in FOR/NEXT loops. In comparison, the Applesoft interpreter converts all integers to real numbers before operating on them. These conversions make interpreted integer arithmetic relatively inefficient. In addition, the interpreter forbids use of integers as loop control variables in FOR/NEXT loops.

These factors all combine to make compiled programs considerably faster. In most cases, execution of compiled programs is two to twenty times faster than execution of the same program under the interpreter.

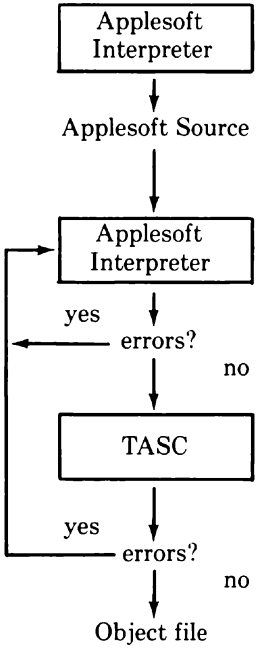
3.3 The Program Development Process

This discussion of the program development process is keyed to Figure 1, The Program Development Process. Refer to Figure 1 for reference while reading this text.

Program development begins with (1) creation of an Applesoft source program. The best way to create and edit an Applesoft program is to use the editing facilities of the Applesoft interpreter.

Once the program has been entered, it should (2) be debugged using the Applesoft interpreter. Since the compiler and interpreter are very similar, running a program with the interpreter provides a much quicker syntactic and semantic check than does compiling the same program.

After the program has been debugged with the interpreter, it then can (3) be compiled. If compilation is successful, the compiler produces an object file that can (4) be executed as a machine language program. If the compiler detects errors, or if errors show up while executing the compiled program, the process starts over at step 2.



1. Create and edit Applesoft source.
2. RUN and debug source with the interpreter.
3. Compile source, creating a binary object file.
4. Execute compiled object file.

Figure 1. The Program Development Process

4. Debugging with the Applesoft Interpreter

Debugging a program intended for compilation is a two step process that involves:

1. Creating the source program, and

2. Running the program under the interpreter to check for errors.

These two steps are described below.

4.1 Creating a Source Program

Creating an Applesoft source program requires the use of the editor available within Applesoft. Programs are created by simply entering Applesoft statements from within Applesoft. Once a program has been created, it can be saved to disk with SAVE. TASC can only compile Applesoft disk files. For more information on creating source files, see the Applesoft and DOS reference manuals.

4.2 Running a Program with Applesoft

Programs should be debugged using the Applesoft interpreter before being compiled. If the program to be compiled uses TASC features that are not available in the interpreter, it may be necessary to debug the program with the compiler. See Chapter 8, Language Enhancements, for other debugging suggestions.

TASC is highly compatible with the Applesoft interpreter. This compatibility allows the Applesoft interpreter to function as the primary debugging tool. The interpreter provides much better debugging facilities than a compiler, since it includes features such

as TRACE. With the interpreter programs can also be halted, and the values of variables examined with immediate mode PRINTing of their values. In addition, an interpreted program can be modified without having to repeat the more lengthy compilation process.

There are some drawbacks to debugging with the interpreter: statements that are only executed under special circumstances may never be examined, and the interpreter halts execution when it encounters the first error in a program.

Debugging with the compiler does not suffer from these drawbacks since the compiler examines every statement in a program, and can continue the compilation even if it encounters errors.

In general, compiling a program is an effective way to check for syntax errors; however, program logic errors are more easily tracked down with the interpreter.

5. Compilation

NOTE

> If a compiled program does not run correctly, see Chapter 10, Error Messages and Debugging, for some possible solutions. Chapter 7, A Compiler/Interpreter Language Comparison, also provides information about possible problems.

This chapter discusses the more technical aspects of compilation. It includes a discussion of the following topics:

1. Options
2. Terminating compilation
3. Compiling large programs

5.1 Options

The demonstration run showed only the most basic type of compilation. TASC includes several options that can be used to control compilation more closely. The requested options control memory allocation and compilation. To explicitly specify the values for these options, simply answer "NO" when the compiler offers the default values.

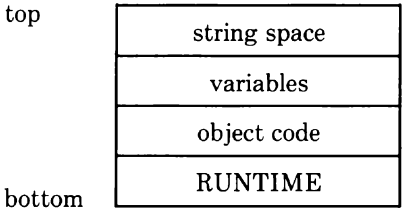
5.1.1 Memory Usage

The memory used by the compiled code at runtime is divided into three areas:

1. RUNTIME Library
2. Object Program
3. Variables

TASC allows the location for each of these blocks to be specified separately. The memory allocation features can be used to protect machine language programs, shape tables, the HIRES screens, or any other important part of memory.

The default allocation order of the blocks is library, program, variables. The library is allocated lowest in memory, and the program and variables follow. The library begins at location 2051, or $803, with the dollar sign ($) indicating a hexadecimal value. The default configuration for memory is:



Alternate addresses for the blocks are simple to specify. The new location for the library is entered as a number, and defaults to $803. Addresses can be specified in either hexadecimal or decimal. Hex addresses must be preceded by a dollar sign ($).

The library must be BLOADed before a compiled program can be run. By default the library is loaded at $803. When a program is compiled to expect the library at a different address, the library

must be loaded in at the correct address by using the "A" option with the BLOAD command. See Appendix A, Moving Binary Files with the ADR Utility, for more information about loading and saving the binary object and RUNTIME files.

The beginning address for the object code may be specified with:

1. The word HGR1
2. The word HGR2
3. A decimal or hex number
4. <RETURN>

HGR1 and HGR2 simply set the beginning of the program above the appropriate HIRES screen. The 4K RUNTIME library defaults to the space below the first HIRES screen. This default library location is suggested for programs that use HIRES graphics. An absolute decimal or hex address may also be specified, but care must be taken when doing so. Beware of overlapping memory allocations. Typing <RETURN> causes the beginning of the object code to default to the end of the library.

Variable space may be specified explicitly or allowed to default. The beginning of variable space defaults to the end of the object code.

Compiled programs use the normal HIMEM pointer to determine the top of available string space, and strings grow downward from there. The bottom of available string space is set so that the block that is highest in memory is protected. Therefore, the normal default order (RUNTIME library, object program, variables) sets the bottom of string storage to the end of variable space. Specifying another block to reside highest in memory sets the bottom of string storage to the end of that block.

5.1.2 Compilation Options

There are five compilation options that can be specified before the compilation process begins.

These options have the following defaults:

COMPILATION OPTION	DEFAULT
Compilation listing	YES
Pause on errors	YES
Integer arithmetic	YES
Integer constants	YES
RESUME/Debug code	NO

Answering "NO" or "N" to the default option prompt provides a chance to turn each of these options on or off.

Compilation listing option

The compiler normally lists the source file. Turning the listing option off suppresses the listing. Errors, warnings, and special messages are printed as usual.

Pause on errors option

Errors normally halt compilation and allow the user to abort or continue compilation. Turning the pause option off suppresses the pause after any error messages are printed.

Integer arithmetic option

TASC includes a full integer arithmetic package. True integer arithmetic allows operations on integers to be performed in about half the normal time. Including the option substantially increases the speed of programs that use integers, but there are some limitations. See Chapter 8, Language Enhancements, for more information on the integer arithmetic package.

Integer constants

Constants in a compiled program can be treated as integers or floating point numbers. Selecting the integer constants option allows constants that are used as integers to be stored in integer format. If a constant is also needed in floating-point form, the compiler includes both forms with the compiled code. Conversion of constants at runtime is totally eliminated. Including the integer constants option increases the speed of programs where constants are accessed as integers.

Integer constants take up two bytes in the object file; the floating point representation requires five. Including integer constants can slightly increase the size of the object code if both real and integer versions are needed, but it can also shorten the code if only the integer representation is required. The integer constants option should normally be left on. See the last section in this chapter, Compiling Large Programs, for more information on handling any problems with longer programs.

RESUME/Debug code option

Turning on the RESUME/Debug code option causes code to handle the RESUME statement to be included in the object program. The RESUME statement in Applesoft allows an error trapping routine to resume execution at the beginning of the statement that caused the error. Unlike some Applesoft compilers, TASC fully supports ONERR GOTO. The compiled version of ONERR GOTO traps all runtime errors, including those that occur within routines from the Applesoft interpreter.

Including the RESUME/Debug option requires the compiler to generate extra code at the beginning of each statement that may generate an error. Selecting the RESUME/Debug code option causes the object code to be larger and somewhat slower.

Turning on the RESUME/Debug code option has the advantage that any runtime error messages include the object code address. Normally, only some of the errors generated by the runtime library include an object code address. The RESUME/Debug option can be useful for debugging with the compiler. However, including it does decrease the speed and increase the length of the compiled code. The RESUME/Debug option should be left off unless it is absolutely needed. If the option is turned off the compiler will ignore all RESUME statements.

5.2 Terminating Compilation

The compiler runs in machine language, so <CTRL-C> would normally be ignored, and <RESET> would be necessary instead. However, the compiler is often accessing the disk, so using <RESET> is inadvisable. To solve this problem, the compiler occasionally checks to see if a <CTRL-C> has been typed, and terminates compilation if it has. The compiler can also be halted by typing <CTRL-C> as the first character of an input response, but this does not correctly terminate compilation.

Since stopping compilation leaves the object file incomplete, TASC deletes the object file if compilation is aborted. TASC modifies DOS, so exiting by using <RESET> or typing <CTRL-C> in an input leaves DOS in its modified state. DOS must be rebooted if the compiler is exited abnormally. Typing <CTRL-C> outside an input is the only way to correctly terminate compilation. Correctly exiting the compiler restores DOS to its normal state.

5.3 Compiling Large Programs

Compact object code, disk-based design, and COMMON variables make TASC an outstanding compiler for large programs. Because of TASC's minimal object code expansion, most large programs can be compiled without modification. However, if a program is simply too large to be compiled or to fit into the available memory, special measures must be taken. The sections that follow describe possible solutions.

5.3.1 Reducing Symbol Table Space

The compiler's symbol table must store information about variables, functions, constants, line number references, and COMMON assignments.

The symbol table is examined before each new entry is made, and this examination prevents duplication of information. The first use of a variable requires the compiler to create a new entry, but later references do not require additional space. Similarly, although initially referencing a line number in a branch instruction creates an entry for the line, multiple references do not require any extra entries.

Functions require four symbol table locations, and line number references require three. Simple variables require five locations, and array variables require six plus one for each dimension. COMMON variables require an additional two locations per variable. In practice, eliminating functions, line number references, or variables is difficult, but it may be possible.

Extremely long programs that exhaust the symbol table space give a "SYMBOL TABLE FULL" error during compilation. There are several ways to correct this problem.

The simplest way is to turn off the integer constants option. With the option on, constants are initially stored as integers. If the constant is later needed as a floating-point number, it is converted and entered into the symbol table as a floating point constant as well. The initial integer entry takes five locations. If the additional floating-point entry is required, it takes up eight locations.

With the integer constants option off, constants are stored only in floating-point form. Turning the option off therefore saves five locations for every constant that is referenced as a floating-point value. Although this savings is usually insignificant, it may be important for long programs with many constants.

Turning the integer constants option off also slows down the object code slightly, so the option should be left on whenever possible. If the SYMBOL TABLE FULL error persists, a program can often be separated into two parts as described below.

5.3.2 Separating a Program into Parts

When the object code for a program does not fit in the available memory, or when a program requires too much symbol table space, the program can often be separated into two smaller programs. Good candidates for this technique are programs that spend most of their time in one section of code, then move on to another section and do not return. A program of this type can quite easily be broken into two smaller programs. The first small program performs the first part of the process, then passes any needed values on to the second program.

Programs without a natural division present more of a problem. With this type of program, an artificial division can often be created. In some cases, the separated programs may have to run each other alternately. Since running programs alternately from disk is very slow, it is preferable to find a division where alternate execution is not required.

Since most programs that are separated into parts need to pass values from one program to another, the usual procedure is to pass the needed values in a disk file. One program writes the information out to disk, and a second reads it in. This is a workable solution, but it is slow when a large amount of information needs to be passed.

Fortunately, TASC is designed to simplify compiling large programs, so this is not necessary. Instead, TASC provides the ability to pass the needed values in COMMON. The variables are simply declared in COMMON statements in both programs, and the

compiler allocates storage so that saving the values on disk is unnecessary. This is the technique that TASC uses to communicate between its three parts: PASS0, PASS1, and PASS2.

The technique of splitting a large program into smaller programs that run in sequence can solve almost any problem with program size. Passing values with COMMON makes separating programs a manageable problem. See Chapter 8, Language Enhancements, for more information about TASC's powerful COMMON features.

6. Executing a Compiled Program

TASC is designed to implement the Applesoft language as closely as possible, so executing a compiled program produces the same results as executing the same program using the interpreter. However, the fact that the object file is a machine-language program stored as a binary file makes the mechanics of loading and running a compiled program different from running an interpreted program.

These differences and other related topics are discussed below:

1. Interpreted programs are stored as Applesoft files. Applesoft files are indicated by an "A" in the disk CATALOG. Interpreted programs are executed by typing RUN <filename>. In contrast, compiled programs are machine language files stored in binary format. Binary files are indicated by a "B" in the CATALOG.

   Since compiled programs are not Applesoft files, attempting to RUN a compiled program gives a FILE TYPE MISMATCH error. Instead, compiled files are executed by typing:

   ```
   BRUN  <filename>
   ```

   The "B" prefix to the RUN command indicates a binary file. When a program is BRUN, the RUNTIME library must already be in memory. If the RUNTIME library is still in memory from a previous program run, and is located where the next program expects it, then the library need not be reloaded.

   The normal sequence for executing a compiled program is therefore:

   ```
   BLOAD  RUNTIME
   BRUN  <filename>
   ```

Compiled programs can only be executed when the Applesoft interpreter is in memory. Compiled programs will not work with Integer BASIC.

2. Use of Ampersand (&) — Once the compiled program has been loaded and executed, it can be re-executed by typing an & followed by a <RETURN>. The compiled program sets the ampersand vector to point to the beginning of the object code when it executes, so the ampersand vector can be used as long as the program is the last program run. Using the ampersand is much more convenient than having to CALL the code explicitly, since CALLing the code requires knowing the address of the beginning of the object code.

3. Halting Execution of a Compiled Program — Since the compiled code is executing directly and is not under the supervision of the interpreter, <CTRL-C> does not function during execution of a compiled program. Unless the object program is explicitly looking for input, any characters typed are ignored.

   However, typing <CTRL-C> as a response to an INPUT statement functions exactly the same as in the interpreter. This means that compiled programs must be interrupted by using <RESET>. <RESET> does not correctly re-initialize the Applesoft interpreter, so a NEW command must be used after interrupting a compiled program.

4. The NEW Command — NEW causes the interpreter to reset pointers, but not to clear the program space. Therefore, a compiled program can be safely re-executed if no program lines have been typed in and stored into the program space.

5. Immediate Commands — The compiled code does not maintain a variable list, so the interpreter cannot find the values of variables used in a compiled program. Executing a compiled program that uses the variable A and then typing the immediate command PRINT A returns a value unrelated to the variable in the compiled program.

7. A Compiler/Interpreter Language Comparison

TASC is designed:

1. To substantially increase the speed of Applesoft programs with minimal code expansion, and

2. To be as accurate an implementation of Applesoft as possible.

Careful design and implementation prevented serious compromise of either goal. TASC produces compact and efficient code that simulates the Applesoft interpreter in very accurate detail. This chapter describes the differences that must be taken into account when compiling programs. If a compiled program does not run correctly, also see Chapter 10, Error Messages and Debugging, for more information.

7.1 Statements Not Implemented

The very nature of compilation makes supporting some features of the interpreter impractical, since the source file is unavailable while the object code produced by the compiler is executing. Therefore Applesoft statements that depend on the source file (such as LIST and DEL) are not available with TASC. The cassette I/O features of Applesoft have also been removed. Most other features of Applesoft are implemented without change.

The following Applesoft statements are not included in TASC:

CONT	DEL	LIST	LOAD
LOMEM:	NOTRACE	RECALL	SAVE
SHLOAD	STORE	TRACE	&

Some other Applesoft statements and features must be used differently in compiled programs. These differences are described in the following sections.

7.2 Features Supported with Limitations

The following Applesoft features are supported with some limitations:

DEF FN DIM <CTRL-C>

The differences between the compiled and interpreted versions of these statements are described below.

7.2.1 User DEFined FuNctions

Both TASC and the Applesoft interpreter allow the definition of single-argument, real-valued arithmetic functions with the DEF FN statement. In addition, the interpreter allows functions to be redefined with a later DEF FN statement using the same function name. TASC **does not** support function redefinition.

In the interpreter, a DEF FN does not define a function until the DEF FN statement is actually executed at runtime. The compiler, on the other hand, scans all function definitions at compiletime. Therefore, function definitions can be located anywhere within the source file, and functions are defined from the beginning to the end of program execution. The source file cannot contain more than one definition for a given function, even if the definitions are identical.

The compiler's treatment of user-defined functions prevents "?UNDEF'D FUNCTION" error messages at runtime. All user-defined function references are matched with the corresponding definition at compile time. References to undefined functions are detected and flagged as errors during compilation.

7.2.2 The DIMension Statement

The interpreter provides three methods of dimensioning an array:

1. Explicit Constant Dimensioning — Executing a DIMension statement in which the specified dimensions are constants sets aside the same amount of storage for the array each time the program is run.

2. Explicit Dynamic Dimensioning — Executing a DIMension statement in which the specified dimensions are arithmetic expressions sets aside space for the array depending on the computed value of the expressions.

3. Default Dimensioning — If an array reference is encountered before a DIMension statement, the array is given the default maximum value of 10 for each dimension of the array. Accessing an element of a three-dimensional array before dimensioning the array produces the default dimensions (10,10,10). Applesoft allows the use of 0 as an array subscript, so an array dimensioned to 10 actually has 11 elements (0-10).

The compiler **does not** support dynamic dimensioning of arrays. Any DIM statements in the program must use **integer** constants, not floating-point values or arithmetic expressions. DIMension statements can be located anywhere within the file, and need not precede the first reference to the array. Arrays can be DIMensioned more than once, but the dimensions specified must be identical. TASC's added INTEGER and COMMON statements can also dimension arrays. See Chapter 8, Language Enhancements, for more information on INTEGER and COMMON. An array that is referenced and not dimensioned receives a default dimension of 10 for each subscript.

References to an array within a DIMension statement or arithmetic expression must be consistent in the number of dimensions used throughout the file. An error is generated if an array is referenced with a number of subscripts that differs from the number first used.

The lack of dynamic array dimensioning can be overcome by dimensioning arrays to the largest possible value allowed within the constraints of available memory. Since keeping dimensions small has little other advantage than conserving memory, all available memory can be assigned to arrays if the maximum subscripts needed for the arrays are unknown.

7.2.3 Use of <CTRL-C> to Halt a Compiled Program

The Applesoft interpreter allows the user to interrupt execution of a program by typing a <CTRL-C>. In addition, typing <CTRL-C> followed by a <RETURN> during INPUT causes the program to halt.

Compiled code does not check for <CTRL-C> during execution. A compiled program can be halted only by using the <RESET> key. However, <RESET> interrupts cannot be trapped by compiled programs. As a result, <RESET> does not properly terminate compiled programs, and a NEW command must be executed to re-initialize the interpreter. See Chapter 6, Executing A Compiled Program, for more information on the use of <RESET>.

While the compiled code does not check for <CTRL-C> during execution, it **does** support the use of <CTRL-C> during an INPUT statement. Typing <CTRL-C> followed by a <RETURN> in response to an INPUT prompt causes program termination and a "BREAK IN ####" message. The compiled INPUT functions the same as the interpreted INPUT.

If necessary, a compiled program can simulate the interpreter's handling of <CTRL-C> during execution by periodically checking the keyboard strobe. See the Applesoft Manual for more information about the keyboard strobe.

7.3 Other Language Differences

A few Applesoft statements have been modified to return reasonable results under a wider variety of conditions. These are described below.

7.3.1 IF/THEN Using Strings

The Applesoft interpreter was not designed to allow the IF/THEN statement to test a string expression. However, the interpreter does not ensure that the expression used in an IF/THEN statement is a number. A string expression can be used in an IF/THEN statement and the interpreter will not detect the error. However, using an IF/THEN with a string expression more than two or three times in a program causes a "?FORMULA TOO COMPLEX" error. In addition, the logical value returned for the string is not consistent.

A string expression is not simply an expression that contains string operands. String expressions are defined as expressions that evaluate to a string result. The following examples evaluate to a string result and are string expressions:

```
CHR$(3)          A$+B$          STR$(I*J)
```

The following examples evaluate to a numeric result and are therefore numeric expressions:

```
A$<B$+C$    A$<CHR$(2)    FLAG AND A$<C$
```

The compiler fully supports the use of IF/THEN in all its forms with a numeric argument, but an IF/THEN statement with a string expression is flagged as an error during compilation. IF/THEN is discussed more completely in the Applesoft Manual.

7.3.2 Numeric GET

The Applesoft interpreter's GET statement was designed for use only with strings. However, it is possible to use it with numeric variables. Unfortunately, the interpreted GET has several problems

that make its use with numeric variables inconvenient. The biggest problem is that the interpreted numeric GET gives a syntax error and stops the program if the input response is non-numeric. The compiled numeric GET eliminates this problem. Entering a non-numeric input does not generate an error message and returns a zero as the entered value.

7.3.3 Numeric READ

The Applesoft interpreter does not allow numeric strings to be read into numeric variables. For example, although the following DATA statements are treated identically when they are READ into a string variable, the second generates a "?SYNTAX ERROR" when it is READ into a numeric variable:

```
10 DATA 1234
20 DATA "1234"
```

The compiled version of READ eliminates this inconvenience. However, the compiled version of INPUT still generates a "?REENTER" message when a quoted number is entered. The interpreter's conventions for leading and trailing spaces in literals and strings are implemented without change.

7.4 Operational Differences

The information in this section describes several additional differences between compiled and interpreted programs. Most of the differences are not usually significant, but they may need to be taken into account in some cases.

7.4.1 The Runtime Stack

Compiled and interpreted programs use part of memory as a stack to store GOSUB/RETURN and FOR/NEXT information. The routines that are used by a compiled program are more stack-efficient than those in the interpreter. Some programs that generate stack overflow errors when executed with the interpreter can, therefore, run without problems once compiled. Although compiled programs use less stack space than interpreted programs, compiled code does **not** check for stack overflow.

There are 254 bytes of free stack space. RETURN entries take two bytes, and FOR entries take 16. The stack overflows if subroutine calls are nested more than 127 levels deep or if FOR/NEXTs are nested more than 15 levels deep. Part of the stack area is also used as scratch space by the Applesoft PRINT and STR$ routines. Using these statements overwrites the last 16 bytes of available stack space. Overflowing the stack or overwriting the top of the stack when it contains information causes a compiled program to behave unpredictably. Since compiled programs are more stack-efficient than interpreted programs, observing the restrictions imposed by the interpreter prevents any problems.

7.4.2 ONERR GOTO and the Stack

The ONERR GOTO statement is the source of most problems with the stack in both compiled and interpreted code. The problems occur when an internal interpreter or runtime routine is exited with an error condition. Most internal routines use a small amount of stack space as temporary storage. Exiting with an error condition may

leave some stored parameters on the stack. When ONERR is not in effect, the program stops execution, and the information on the stack does not cause any problems.

When ONERR GOTO is used to handle errors, the extra stack entries are left on the stack and control is transferred to the error handling routine. If the error-handler ends with RESUME, the stack is restored to its state before the error, and the extra bytes do not cause a problem. However, if the error-handler returns without executing a RESUME, the left-over information on the stack is never removed. Repeating this process too many times causes the stack to overflow.

Most of the problems mentioned in the Applesoft Reference Manual concerning the use of ONERR with certain statements stem from problems with the stack. The Applesoft Manual includes a machine-language program that restores the stack to its state before the last error.

Calling this routine at the end of an error-handler restores the stack and prevents overflow. This routine also resets the stack when used in a compiled program. However, the compiled code does not usually save the stack pointer before each statement. When the routine tries to restore the stack to its previous state, it will set the stack pointer incorrectly.

To prevent this problem, the compiled code must save the stack pointer before each statement. The RESUME statement also requires the compiled code to save information before each statement. Generating the extra RESUME/Debug code is a compilation option, since it slows down execution and makes the program longer.

The extra RESUME code **must** be included in the compiled program if the Applesoft manual's stack clear routine is to function correctly. Failure to include the extra code will cause the compiled program to jump into the monitor or encounter other problems. Since including the RESUME code slows the program and makes the object file longer, the stack clear routine should not be used unless absolutely necessary.

Programs that use the stack clear routine can usually be recognized by CALLs in their error-handling routines. See the Applesoft manual under ONERR GOTO for information about the stack clear routine, see Chapter 5, Compilation, for information on invoking the RESUME option.

7.4.3 Special Machine Language Calls

A few Applesoft programs use special techniques for passing information to machine-language routines. The most common method is to include extra text following the machine-language call. For instance, the following statements might be used:

```
USR(0)"3,5,6"
CALL  520"PROGRAM 2"
```

These statements work with the interpreter only because the machine language program can change the interpreter's pointer into the current statement and prevent the added characters from being seen. Since the compiler scans all statements at compile time, the extra text will be flagged as a syntax error. See the section on COMMON in Chapter 9, Language Enhancements, for more information on passing parameters to machine-language programs.

7.4.4 Using MAXFILES from within a Compiled Program

The DOS MAXFILES command sets the number of file buffers available. The number of buffers available determines how many files can be open simultaneously. Since TASC fully supports all DOS commands, the MAXFILES command can be used from within a compiled program. However, DOS does not perform the additional operations needed to correctly execute MAXFILES in a compiled program. DOS changes the value stored in the HIMEM location, but DOS does not alter other pointers that must be changed so that a compiled program will conform to the new HIMEM value.

MAXFILES in a compiled program must be followed by a HIMEM statement to set all pointers correctly. The HIMEM statement

should simply specify the new HIMEM value provided by the MAXFILES command. This can be accomplished with the following statement:

```
HIMEM: PEEK(115) + 256 * PEEK(116)
```

Using HIMEM in either a compiled or interpreted program destroys the current string values, so HIMEM and MAXFILES should usually be used as the first statements in a program.

7.4.5 Using RUN with COMMON

The Applesoft RUN command is normally used as an immediate command from the editor, but the interpreter also allows it to be included in a program. RUN in an interpreted program clears all variables and re-executes the program. RUN with the optional line number specified also clears all variables, but begins execution at the specified line rather than the beginning of the program.

TASC also includes the RUN command. RUN without the optional line number re-executes the program by jumping to the ampersand vector. The re-execution causes the same clearing action that initially began the program. If the program has no COMMON variables, or specified them with USECOMMON, then only local variables are cleared. If the program specified DEFCOMMON, then both COMMON and local variables are cleared.

Use of the RUN linenumber form of the RUN command causes a CLEAR, followed by a GOTO to the specified line. COMMON variables are never cleared, since the compiled CLEAR command only initializes local variables. See Chapter 8, Language Enhancements, for more information on COMMON and CLEAR.

7.4.6 NEW, END, and STOP

The NEW statement in an interpreted program erases the current program before terminating execution. STOP prints the message "BREAK IN ####" before termination, and END simply termi-

nates execution. The compiled NEW and END statements function identically. STOP still prints the BREAK message, but the number specified is an object code address, not a line number. All three commands delete any interpreted program in memory, initialize all Applesoft pointers properly, then re-enter the interpreter.

7.4.7 Abnormal Termination of a Compiled Program

Although the compiled and interpreted versions of a program produce the same output, the internal process being carried out is substantially different. Both the compiled code and the interpreter make extensive use of memory page zero, which resides at $00-FF (decimal 0-255). Many of the locations used by the interpreter are used for a different purpose when a compiled program is running. See the Appendix F, Zero Page Usage, for a description of how the zero page is used by a compiled program.

Compiled programs begin with a call to an initialization routine that sets up the zero page for execution of the compiled program. When the compiled program executes an END, STOP, or NEW statement, or is interrupted by <CTRL-C> during an INPUT statement, it re-initializes page zero for the interpreter before terminating execution. This terminates the compiled program properly.

Using <RESET> to interrupt a compiled program stops the program, but does not re-initialize the zero page for the interpreter. Runtime errors also stop the program without re-initialization. Attempting to use the interpreter at this point is unwise. Even if statements appear to function normally, the interpreter may be destroying DOS or making other errors. A NEW command is necessary to properly re-initialize the interpreter. NEW sets the pointers stored on page zero to their correct values, allowing the interpreter to operate normally.

7.4.8 Applesoft Pointers Preserved by Compiled Code

There are only two pointers used by the interpreter that are preserved during execution of a compiled program. These two pointers are MEMSIZ and TXTTAB. MEMSIZ is the top-of-memory pointer affected by the HIMEM statement, and TXTTAB is the beginning-of-program pointer. They reside at $73-4 (decimal 115-6) and $67-8 (decimal 103-4), respectively.

Compiled programs use MEMSIZ for the same purpose as the interpreter, and the compiled HIMEM statement changes the contents of MEMSIZ.

Compiled programs do not use TXTTAB, but the interpreter uses TXTTAB to point to the beginning of the current program in memory. The interpreter and DOS also use TXTTAB to decide where a LOADed program should begin. Compiled programs preserve TXTTAB so that a compiled program can easily RUN an interpreted program using DOS.

The program storage format used by the Applesoft interpreter requires that the location just before the program area pointed to by TXTTAB contains a zero. A program can still be entered when the location is not zero, but attempting to RUN the program produces a "?SYNTAX ERROR". This restriction also holds when using DOS to LOAD or RUN interpreted programs. The location does not usually have to be explicitly zeroed, since TXTTAB normally points to its default location of $801. $800 is set to zero when Applesoft is initialized, so leaving TXTTAB at its normal value alleviates any problems.

To maintain this convenience, the compiler leaves location $800 protected in its default memory allocation mode. Preserving this location allows compiled programs to RUN interpreted programs without first having to store a zero in $800. $801-$802 are protected for similar reasons, so the default address for the library is $803 (2051 decimal).

7.4.9 Linking between Compiled Programs

Interpreted programs are linked using the DOS RUN command. Since compiled programs are binary files, not Applesoft programs, attempting to RUN an object file produced by the compiler produces an error.

Compiled programs are linked using the BRUN command. To facilitate linking, TASC allows COMMON variables, a powerful extension that is not available in the Applesoft interpreter. Programs executed in sequence can use COMMON variables to pass information. See the next chapter, Language Enhancements, for an explanation of this new feature.

7.4.10 String Operations

TASC handles strings differently than the interpreter. The interpreter usually duplicates string values in an assignment such as A$=B$. If thirty strings have the same string value, the interpreter normally stores the same string thirty times in memory. The copying strings makes the interpreter especially slow in applications that move strings frequently.

TASC eliminates string copying by allowing several strings to point to the same value in memory. This eliminates the need to duplicate strings and makes operations like sorting much faster. In exchange for being very fast in assignments, TASC is slightly slower on operations that build and take apart strings. LEFT$, RIGHT$, and MID$ are less efficient. Since these functions are normally used less often than string assignments, the modified method used in TASC is more efficient overall.

The biggest speed problem in string operations is usually garbage collection. Both the interpreter and TASC must "house-clean" when the available string space is filled. Garbage collection compacts the strings that are still being used, and eliminates any string "garbage" that is no longer needed.

The frequency of garbage collection (GC) is determined by two factors: the amount of free space available and the rate of garbage production. The amount of free space affects how much garbage can accumulate before GC is necessary. In turn, the rate of garbage production determines how quickly the space is filled.

GC is normally a lengthy process. The time required for GC depends on how many string variables are used in a program. Large string arrays substantially slow garbage collection, since the GC routine must look through more variables to decide whether a string should be kept or discarded. Each time that GC is necessary, the program simply suspends execution while the GC routine house-cleans.

The number of times that GC is necessary can be reduced by increasing the string space available or decreasing the rate of garbage production. More space can be obtained by reducing the size of arrays, shortening the program, or setting DOS MAXFILES to a smaller number. The rate of garbage production can be decreased by holding operations such as LEFT$, RIGHT$, MID$, and string concatenation (+) to a minimum. Since the compiler does not duplicate strings for assignments, the number of assignments is not a factor.

The time spent during each GC call can be reduced by decreasing the number of string variables. The time required for GC is roughly proportional to the square of the number of string variables, so cutting the number of variables in half usually makes GC about four times faster.

The string operations in TASC are quite fast, and keeping the number of GC calls to a minimum results in the best performance. Using string operations efficiently can make a substantial difference in execution speed.

8. Language Enhancements

TASC provides two major enhancements to Applesoft that offer substantial increases in speed and programming power:

1. True integer arithmetic, integer FOR/NEXT loops, and
2. COMMON variables.

TASC makes these enhancements possible by including five new statements:

CLEAR CHAIN	CLEAR COMMON	DEFCOMMON
INTEGER	USECOMMON	

These new statements and the language enhancements they allow are discussed in the sections that follow.

8.1 Integer Arithmetic

TASC includes a full integer arithmetic package. The integer math routines allow very fast operations on integers, and are a major improvement over the methods used by the interpreter.

8.1.1 Integer Arithmetic in Interpreted Programs

The Applesoft interpreter includes the use of integer variables, but it does not actually perform integer operations. All integers are converted to floating point numbers before being operated on. Since this conversion is necessary each time the variable is accessed, operations on integer variables are actually slower than operations on floating-point variables.

Because Applesoft does not include integer operations, the only advantage to using integers in the interpreter is that elements of integer arrays occupy two bytes of memory rather than five. The interpreter also does not allow an integer variable as the index to a FOR loop. These problems combine to make the use of integer variables in interpreted programs of little value.

8.1.2 Integer Arithmetic in Compiled Programs

Programs compiled with TASC can show a substantial increase in speed if real variables are changed to integers. However, converting a program by adding a % sign to each variable name is time-consuming. To eliminate this problem, TASC includes the declaration statement INTEGER. INTEGER allows variables to be defined as integers without the addition of the normal % sign. As an example, the real variable I can be declared as an integer by simply including the statement INTEGER I.

8.1.3 The INTEGER Statement

Since the interpreter does not recognize the INTEGER statement, including it as a normal statement causes a syntax error if the program is run under the interpreter. To avoid this problem, the INTEGER statement must be included in a special "active" REM statement. To allow the compiler to distinguish these special REM statements, "active" REMs are distinguished from normal "non-active" REMs by using an exclamation point after the word REM. For example, the following statement declares I as an integer variable:

```
10 REM! INTEGER I
```

The other added statements described later must also be disguised in active REMs. The new statements are ignored when the program is run by the interpreter, but are recognized by the compiler and treated as normal statements.

The INTEGER statement can declare either arrays or simple variables as integers. Arrays are declared by including the name and dimensions in the same form they would be used in a DIM state-

ment. The dimensions specified must be identical to the dimensions in any other INTEGER, DEFCOMMON, USECOMMON or DIM statements. DEFCOMMON and USECOMMON are discussed later in this chapter.

Multiple variables can be declared as integers by separating the variable names with commas. Spaces are allowed between variable names and commas, but may not be embedded within variable names or array dimensions.

Since many programs can declare all their variables as integers, TASC includes a wildcard option for INTEGER. Using an asterisk (*) as the first non-space character following INTEGER causes all numeric variables to be treated as integers. The effect of including INTEGER * is the same as putting the name of every real variable and array in an INTEGER statement.

A variable may be declared as INTEGER several times, but only the first declaration has any effect. Multiple INTEGER statements are allowed. The following declarations are all acceptable:

```
10 REM! INTEGER I,J,K,L
20 REM! INTEGER I,J , AB(3,9), R(3)
30 REM! INTEGER *
```

The following declarations include spaces embedded within variable names, and are therefore unacceptable:

```
10 REM! INTEGER A % ,A 2, A 3
20 REM! INTEGER BA( 3, 7), D %(3,7)
```

INTEGER statements can follow or be mixed with normal inactive REMs, but they must precede all other statements in the program. The compiler scans all REM statements, and ignores those whose messages do not begin with an exclamation mark. It also ignores REMs that do not contain one of the keywords INTEGER, COMMON, CLEAR COMMON, or CLEAR CHAIN. During compilation, the compiler notifies the user that it has processed an active REM by printing "RECOGNIZED" on the screen. This message is displayed even when the listing option is turned off. These messages must be monitored carefully, since an incorrect active REM that is not being RECOGNIZED is otherwise hard to detect.

8.1.4 Integer FOR/NEXT Loops

The interpreter does not allow integer variables denoted by a percent sign (%) to be used as loop variables in FOR/NEXT loops. The INTEGER statement allows TASC's integer FOR/NEXT loops to maintain compatibility with the interpreter.

Instead of modifying Applesoft syntax and allowing normal integer variables as FOR loop index variables, TASC's integer FOR/NEXTs use integer variables declared with the INTEGER statement. For example:

```
10 REM! INTEGER I
20 FOR I = 1 TO 10 : PRINT I : NEXT I
```

The INTEGER statement solves the problem of interpreter compatibility, since the control variable is treated as a real variable by the interpreter. TASC recognizes the loop variable as an integer and produces special code for the loop. Since the loop variable is an integer, the initial, final, and step values are considered as integers, and must be in the range -32767 to +32767. Integer loops are usually about twice as fast as their real counterparts.

8.1.5 Integer Operations

Integer values in an expression cannot always be operated on in integer mode. If the operation also contains real variables, or if the integer is used as an argument to a function that expects a floating point value, the integer will be converted to floating point form.

The use of some integer operations is controlled by the setting of the integer arithmetic option. Addition, subtraction, multiplication and negation can generate overflows in the integer accumulator, so their use can be explicitly controlled. If the option is on, true integer operations are performed whenever both operands are integers.

If the switch is off, integer operations are only performed for comparisons and logical tests. Since these operations cannot generate an overflow, their use is automatic and is not controlled by the setting of the integer arithmetic option.

Integer operations should be turned off only as a last resort. If including true integer arithmetic causes overflow in only a few cases, the expressions that produce overflows can be forced into real mode. For instance, if the integer-mode addition of the two integers A and B produces an overflow, A can be temporarily assigned to a real variable before the addition, and B can be added to the real variable instead. Since one of the addends is a real variable, B is converted to floating point form, and the addition is forced to real mode. This forcing technique requires some small modifications to the program, but the added speed produced by using integer operations elsewhere in the program usually justifies the changes.

Many Applesoft statements and functions use integer parameters. Since the interpreter treats all values as floating point numbers, it must compute the parameters as floating point numbers, then convert them to integers. Similarly, a few functions return integer results, and the interpreter must convert the results back to floating point form. These continual conversions often substantially slow interpreted programs.

Since compiled code can evaluate expressions in integer mode, functions and statements that expect or return integer values can be made much faster by using them with integer expressions. Graphics statements, string functions, and game controls all expect integer parameters. Using integer expressions as the arguments to these operations substantially increases their speed. Eliminating the conversions that are normally necessary often doubles the speed of the operation. Games and graphics programs usually benefit substantially from this technique. The compiled code always converts parameters if necessary, but the conversion makes the operation slower.

The following operations expect integer values:

CHR$	COLOR=	DRAW
FOR (integer)	HCOLOR=	HLIN
HPLOT	HTAB	IN#
LEFT$	LET (integer)	MID$
ON GOSUB/TO	PDL	PLOT
POKE (2)	PR#	RIGHT$
ROT=	SCALE=	SCRN
SPEED=	SPC	subscripts
TAB	VLIN	VTAB
WAIT (2 & 3)	XDRAW	

Numbers in parentheses indicate which parameters are treated as integers when the operation has parameters of mixed types.

The integer arithmetic package always performs integer comparisons when both operands are integers. Since division usually produces fractional results, division is always performed in real mode. The following operations can be performed in integer mode when all operands are integers and the integer math package is turned on:

addition	multiplication
negation	subtraction

The following operations can take either floating point or integer values without forcing conversion:

AND	FRE	IF/THEN
NOT	OR	POS

All other operations expect floating point values. Variables should be typed as floating point or integer depending on which way they are used most often in the program. Failing to convert variables that can normally be treated as integers will unnecessarily slow the compiled code. On the other hand, if a variable is normally needed in floating point form, it should be left as a real variable. Matching the types of the parameters supplied to the types expected results in appreciable speed increases.

The following operations return integer values:

ASC	LEN	PDL
PEEK	POS	SCRN

The values returned by these operations should be treated as integers whenever possible to increase speed and prevent conversions.

Using the integer features provided in TASC will substantially improve the execution speed of compiled programs.

The importance of effectively using integers cannot be over-emphasized.

8.2 CHAIN with COMMON

TASC provides another important extension to Applesoft, the ability to pass COMMON variables between chained programs. The addition of COMMON allows several programs to pass values without having to alternately store and recall the values to and from disk. The implementation of COMMON in TASC is normally referred to as "blank" COMMON. Blank COMMON uses a single COMMON block. COMMON is implemented by allocating a static block of memory for the COMMON variables to occupy. This block of memory is left protected as the chained programs are BRUN in succession, and each program refers to the same block of values as it executes. Variables that are declared as COMMON in a program are allocated in the block in a specific order so that variables in different programs can correspond.

The actual names used to refer to the variables do not matter. The common memory allocation is responsible for the correspondence. For instance, assume PROGRAM1 declares variable A1 as its first COMMON variable, and PROGRAM2 declares variable A2 as its first COMMON variable. Since the location of the two variables in the COMMON block is the same, the value left in variable A1 at the end of PROGRAM1 is the initial value of variable A2 at the beginning of PROGRAM2.

8.2.1 USECOMMON and DEFCOMMON

The DEFCOMMON and USECOMMON statements are used to declare COMMON variables. Both forms of the COMMON statement must be included in an active REM as shown below:

```
10 REM! DEFCOMMON I,J,K
```

Multiple COMMON statements are allowed. Any INTEGER declarations must precede COMMON statements, and both must precede any other statements except normal inactive REMs. Incorrect ordering produces the DECLARATION error during compilation. COMMON may specify any type of variable in either simple or array form.

Variables may be declared in both INTEGER and COMMON declarations. Specifying a variable more than once in a COMMON statement causes the DECLARATION error during compilation. Arrays are specified in the same way as with INTEGER, and the same rules hold; any DIM statements must specify the same dimensions for the array.

DEFCOMMON sets up a COMMON block and initializes the variables in it, while USECOMMON accepts a COMMON block already set up by another program without clearing the block. DEFCOMMON presents a problem when several programs chain back to a main menu. Using DEFCOMMON in the menu would cause information returned from the subprograms to be erased, but USECOMMON would fail to initialize the COMMON block at all.

The solution is to add another program containing DEFCOMMON that chains to the menu program, and then use USECOMMON in the menu:

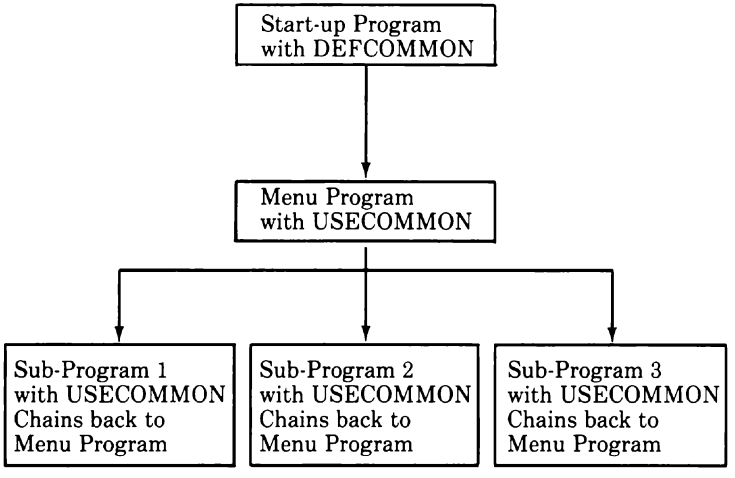


Figure 2. System of Programs Using DEFCOMMON and USECOMMON

The start-up program is initially executed to set up the COMMON block. It then runs the menu program and is **never returned to**. This arrangement prevents the DEFCOMMON from erasing the COMMON variables each time the menu is chained back to.

8.2.2 CLEAR CHAIN and CLEAR COMMON

Since COMMON variables are normally intended to be passed to a later program, the compiled version of the Applesoft CLEAR statement does not clear COMMON variables. TASC provides an additional statement, CLEAR COMMON, that clears COMMON variables. CLEAR COMMON does not affect local variables. CLEAR COMMON must be used in an active REM.

Programs chained with COMMON are linked as usual by using the BRUN command. However, an additional CLEAR CHAIN statement must be included immediately before the BRUN statement. The CLEAR CHAIN command sets up string storage so that strings are properly preserved across the chain. Failure to execute a CLEAR CHAIN causes some string values to be lost or modified. CLEAR CHAIN forces garbage collection and re-initializes all local variables. CLEAR CHAIN must be included in an active REM on the line before the BRUN command.

8.2.3 How COMMON Variables Work

Space in the COMMON block is allocated in the order that the COMMON variables are declared. Integers occupy two bytes, and real numbers occupy five. String variables require two bytes each, but since they are allocated in a separate portion of the block, there is no possibility of mixing them with numeric variables. The compiler's string format is different than the interpreter's. The length byte for a string is stored at the beginning of the string value rather than with the pointer to the string.

Arrays are allocated with the rightmost subscript varying most quickly, i.e, A(1,1) A(1,2) A(2,1) A(2,2). Each element occupies two or five bytes according to its type.

Space in the COMMON block is divided into two sub-blocks, numeric variables and strings. Within each sub-block the order of variable space allocation is determined by the order in which the variables are declared in COMMON statements. When the compiled code is executed, it checks to make sure that the size of the numeric and string COMMON blocks it expects is identical to the size of the blocks actually passed to it by the previous program.

This is the extent of the type checking performed. The compiler does not protect or prevent the user from accessing the ten bytes declared as two five-byte real numeric variables in one program as five two-byte integer variables in another program. This type of error can be avoided most easily by making the COMMON declarations in the two programs identical. Mismatched COMMON block sizes produce the "?TYPE MISMATCH" error at runtime.

COMMON can also be used to pass parameters to machine language routines. The beginning of the block and the positions of the variables within the block are fixed, so machine language programs can reference static locations for the variables. The compiled program can also POKE the variable values into a predetermined location before calling the machine language routine. Some routines designed for interpreted programs locate variables by looking them up in the interpreter's variable list. These routines will not work with a compiled program, since the variable list is eliminated. These programs must be modified to use COMMON or POKE values explicitly.

8.2.4 Notes on COMMON

Space for the COMMON block is allocated at the beginning of the space declared for program storage. Programs that share a COMMON block must all be compiled with the same starting address for the program space. As the compiler scans the COMMON statements, it increments the starting memory address of the compiled program to leave room below it for the COMMON variables. Including a GOTO or transfer to one of the REMs that declare the COMMON block causes the compiled program to jump into the COMMON block, producing undefined results.

Since COMMON is not included in the Applesoft language, using the interpreter to debug programs that use the compiled COMMON is difficult. However, DOS provides a machine language program that can simulate most of the facilities of the compiled chain with COMMON. See the Apple DOS manual under CHAIN for more information.

An alternative debugging method is to simulate the COMMON block by using disk files. PRINTing and INPUTing the COMMON variables in the same order that they occur in the common block will help to detect any ordering errors. This method requires modifying the programs, but it also provides a reasonably good simulation of the compiled COMMON.

8.2.5 Creating a System of Programs

The DEFCOMMON and USECOMMON statements are designed for creating large systems of Applesoft programs that communicate with each other. A sample situation is described here to show possible interactions in a large system of programs. The distinction between BRUN with COMMON and a simple BRUN is also demonstrated.

Consider the following integrated accounting system containing three packages for general ledger, accounts payable, and accounts receivable. Entry into each package is controlled by a main menu program. The system structure is shown below:

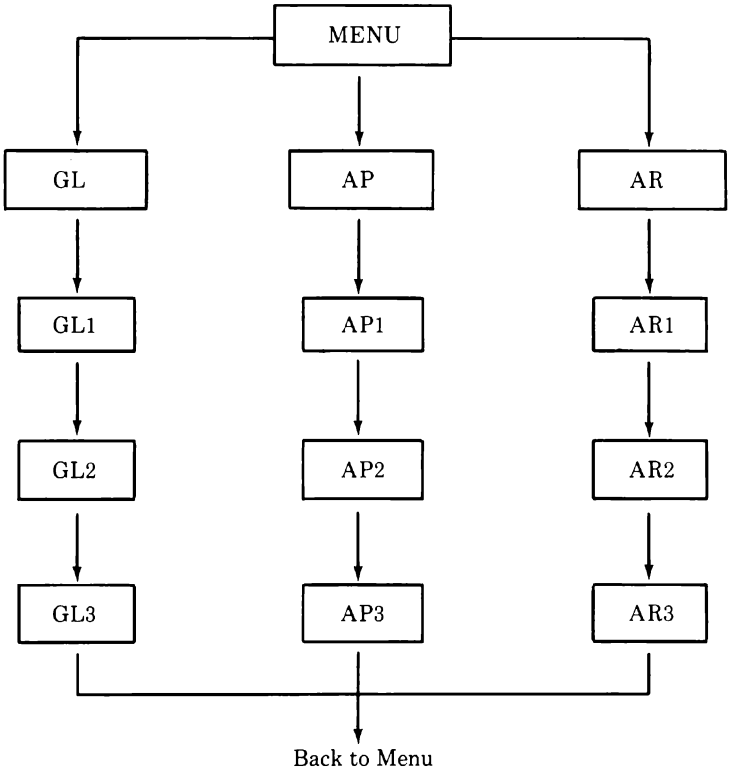


Figure 3. System of Programs Controlled by a Main Menu

In order to use COMMON effectively, it is important to logically structure the system and the COMMON information. In the system pictured above, the subprograms within each of the three packages must pass information to each other.

There may also be COMMON information between the MENU and each of the packages. However, since COMMON blocks must be the same size in programs that communicate with each other, any information passed in COMMON from the MENU also has to be included in the COMMON blocks of the other programs.

Two possible solutions to this problem of communicating between programs are:

1. Use the same COMMON declarations in all programs so that all COMMON information may be shared, or

2. Use the same set of COMMON declarations within each of the three packages, with no information shared via COMMON with the other packages or the main MENU program. In this case, there are three sets of COMMON declarations, one for each package.

For a large, integrated set of programs, the second method gives more flexibility. Since program control is switched from package to package through the main MENU, there is little loss of flexibility with this method. Any input information that would usually be passed from the MENU should instead be obtained in the main program for each of the three packages.

The following program fragments demonstrate how the programs in the figure might be linked. The short fragments also provide examples of when to use a simple BRUN and when to use BRUN with COMMON:

MENU

```
      •
      •
1000  INPUT "WHICH PACKAGE? "; N
1010  IF N = 1 THEN PRINT D$ "BRUN GL"
1020  IF N = 2 THEN PRINT D$ "BRUN AP"
1030  IF N = 3 THEN PRINT D$ "BRUN AR"
```

GL

```
10    REM! DEFCOMMON A, B(3,4), C$
      •
      •
1000  REM! CLEAR CHAIN
1010  PRINT D$ "BRUN GL1"
```

GL1

```
10    REM! USECOMMON A1, B1(3,4), C1$
      •
      •
1000  REM! CLEAR CHAIN
1010  PRINT D$ "BRUN GL2"
```

GL2

```
10    REM! USECOMMON A2, B2(3,4), C2$
      •
      •
1000  REM! CLEAR CHAIN
1010  PRINT D$ "BRUN GL3"
```

GL3

```
10    REM! USECOMMON A3, B3(3,4), C3$
      •
      •
1000  PRINT D$ "BRUN MENU"
```

The examples are shown for the GL package. The other two packages would be similar. Notice that the MENU does not have a COMMON declaration, since it does not pass or receive information. GL has a DEFCOMMON declaration because it must pass information on to GL1, but it does not receive information from the MENU. Declaring DEFCOMMON sets up the COMMON block and initializes it.

GL uses a CLEAR CHAIN before the BRUN, since GL must pass information on to GL1. GL1 declares USECOMMON, since GL1 must receive and not initialize the COMMON block passed by GL.

GL1 includes a CLEAR CHAIN in order to pass information on to GL2. GL2 is similar to GL1, and passes the COMMON information on to GL3. GL3 also declares USECOMMON so that it can accept the values passed to it by GL2. GL3 does not need a CLEAR CHAIN before the BRUN, since no information is passed from GL3 back to the menu.

9. How the Compiler Works

This chapter explains how TASC works, and should make the internal operation of the compiler less mysterious. An understanding of how the compiler works is not necessary in order to use it.

The primary function of the compiler is to translate the source program into machine language. This process is divided into two basic steps:

1. Syntax analysis — The recognition of Applesoft statements that the compiler takes as input

2. Code generation — The production of machine-language equivalents for the Applesoft statements

Discussion of these two major steps is preceded by a description of the programs that perform them.

9.1 PASS0, PASS1, and PASS2

TASC is a "two-pass" compiler, since it compiles in two major steps. PASS0 simply picks up user inputs and sets up compilation parameters, so it is not really part of the actual compilation process. The Applesoft program TASC runs PASS0.

PASS0 and PASS1 chain to PASS1 and PASS2, respectively. All three passes were written largely in Applesoft, and TASC was used to compile itself.

PASS1 is the first pass. PASS1 performs syntax analysis and generates most of the code. As it examines the program, PASS1 also collects information about variables and line numbers and stores the information in a symbol table.

The symbol table is used to store all the information about the program. "Compiling" all this information and inserting it where

it is needed eliminates the runtime searching that occurs during interpretation.

Since PASS1 cannot allocate variable storage or know the addresses of all the line numbers until it has processed the entire program, it cannot insert actual addresses into the code it generates. Instead, it must leave a trail so that the addresses can be patched in later. PASS2 performs this patching after PASS1 has finished processing the source file.

PASS2 uses the information provided by PASS1 to allocate variable storage. PASS1 keeps a record of variable usage in the symbol table, so PASS2 uses the symbol table to allocate storage. PASS2 uses the stored variable types to decide how much storage to allocate, then saves the address of the storage allocated for each variable with the other information about the variable.

Line numbers are handled slightly differently. Keeping all the line numbers and addresses in memory requires too much memory, so PASS1 stores the addresses of the line numbers in the disk file "CLINENUM" as it generates the code. PASS2 uses this file to match line number references to their actual addresses.

With the actual addresses determined, PASS2 must find all the references left undefined in PASS1. Rather than keeping a huge list of all the locations in the program where each variable is used, PASS1 links all the references for each variable or line number into a chain. Each reference contains the address of the previous reference, rather than the unknown address.

Since the file is processed forwards, these chains lead backward from the current position toward the beginning of the file. PASS1 keeps the most recent reference in the symbol table. The symbol table reference points backward to the next most recent, that one points to the one before it, and so on.

This linking leaves PASS2 with the end of the chain for each set of references, and PASS2 uses the chains to trace backwards and patch the undefined references. This process is described as "backpatching", and it is the sole purpose of PASS2. Backpatching disk files is necessarily a slow process, but building the files on disk removes the program length limitations imposed by RAM-based compilation.

9.2 Syntax Analysis

Syntax analysis is the first step in the compilation process, since the compiler must be able to understand the source program before it can generate code. The syntax analyzer must examine the current line of input and decide what statement it represents before it can tell the code generator what kind of code to produce.

The process of recognizing statements can be broken into two parts: lexical analysis and parsing. These two steps are demonstrated by reading a sentence. Grouping letters into words is lexical analysis; grouping words into sentences is parsing.

9.2.1 Lexical Analysis

The lexical analyzer looks at the characters in the input line and separates out the words that are part of Applesoft statements. These words, like PRINT, FOR, etc., are called "keywords". A lexical analyzer might take "FORI=ABTOC" and produce "FOR I = AB TO C". The lexical analyzer substitutes a numeric "token" for each keyword it finds, making the keywords easy to recognize later. Tokenizing "FOR", "=", and "TO" in the previous example might produce "<129> I <208> AB <193> C".

The interpreter lexically analyzes each program line as it is typed in, so Applesoft programs are stored in "tokenized" format. When a program is LISTed, the interpreter substitutes the appropriate word for each token, and the program comes out in readable form. Programs stored on disk are also in tokenized format.

9.2.2 Parsing

Since the Applesoft interpreter tokenizes programs, TASC does not have to perform lexical analysis. However, TASC must still parse the input. Parsing is normally accomplished using one of two approaches: top-down or bottom-up. Both methods produce the same result; they take an input that has been lexically analyzed and identify logical groups of information. Top-down parsing first assumes that the input is a certain statement, then attempts to find the parts that should be there. Bottom-up parsing first examines the

parts, then deduces what type of statement they represent. Most Applesoft statements can be identified by looking at the first character, so TASC parses statements top-down.

Expressions must also be parsed. Even though they are not composed of letters and words, expressions still include symbols that the compiler must be able to organize and understand. The parser must examine the expression and decide how it should be evaluated. The parser uses operator precedence rules and any parentheses present to decide what operations must be performed first.

The code generator does not consider precedence, so the parser has to reorder the operations so that they can be output sequentially during code generation. Expressions are parsed bottom-up, and reordering is accomplished with a stack.

The reordered expressions are passed to the code generator in the form of "triples". A triple is a unit consisting of an operator and one or two operands. Operations or functions that have only one operand leave the space for the other unused. The operand of one triple is often the result of a previous triple. The following set of triples represents the expression A + B * C:

triple #	operator	left operand	right operand
1	load	B	
2	load	C	
3	multiply	triple 1	triple 2
4	load	A	
5	add	triple 4	triple 3

Triples #1 and #2 simply indicate that the variables B and C must be loaded. Triple #3 instructs the code generator to generate a multiplication of B and C. Triple #4 indicates that the value for A must be loaded. Triple #5 specifies that A should be added to the result produced by the multiplication in triple #3.

9.3 Code Generation

Code generation takes place in two different ways. Code for expressions is generated by an explicit call to the code generator with a set of triples. Code for statements is generated during syntax analysis. For instance, the call to the CLEAR routine is generated as soon as the syntax analyzer recognizes the CLEAR statement. This method is called syntax-directed code generation. Most statements like END, GR, TEXT, etc. are represented by a single call to a library or Applesoft routine.

Statements that involve expressions are normally also a single call. The syntax analyzer recognizes the statement, then parses the expression. A call to the code generator produces the instructions to evaluate the expression, and the syntax analyzer finishes the code for the statement with a machine language call to the routine that uses the value.

The interpreter must search lists of variables and line numbers in order to find a variable or line number. The compiler, on the other hand, generates absolute addresses for variables and line numbers. The compiler achieves most of its increase in speed over the interpreter by using these absolute addresses instead of searching long lists.

Rather than searching for things at runtime, the compiler collects all the information about the program at compiletime. Instead of having to search for a line number when it encounters a GOTO 80, the compiled code simply jumps to the address already provided by the compiler.

Compilation allows the compiled code to execute without searching through lists. In exchange, the compiler must perform all the searching and organization at compile time.

9.4 Special Techniques

TASC was designed with minimal object code expansion as one of the main objectives. Execution speed of the object code was also considered, but a slight decrease in speed is occasionally traded for a worthwhile reduction in object code size. TASC is designed for all types of programs, but it is intended to be especially outstanding for large programs and systems. Most compilers produce object code that is substantially larger than the original source, and this creates real problems when the program to be compiled is already large. Speed is important, but a fast program that won't fit in the available memory is worthless. With this in mind, TASC uses several special techniques to generate compact code.

9.4.1 Variable Accessing

Variable accessing is typically a major source of code expansion. Compiled and interpreted code must both load and store values to variables. Variable accessing is required almost constantly, so most compilers use general purpose load and store subroutines. Using subroutines saves quite a bit of space. The routine to transfer a value to and from memory can be included in the object code only once, rather than being duplicated each time it is needed.

Since these subroutines are handling the load and store operations for all the variables in the program, they must be given information about which particular variable to load or store. The information passed to the subroutine is normally the memory address of the variable. The address of the variable to operate on must be passed to the subroutine each time the routine is called. The address is normally passed in two of the microprocessor registers. Every time a variable is accessed, the same process must be repeated; load the registers, call the routine, load the registers, call the routine.

Setting up the registers to pass the address more than doubles the amount of code required for each variable access. There is a more space-efficient way to perform the same process. Instead of having to pass an address to a general purpose routine, it is more effective to have a special routine **for each variable** that performs the load and call.

The special subroutine for the variable takes the same amount of space as one load and call to the general purpose routine, but now each access for that variable can simply call the specialized subroutine. Since the subroutine is dedicated to only one variable, it does not need to be passed an address to indicate which variable it should operate on. Each access used to require both a load and call, but with the new specialized routines for each variable, the address no longer needs to be loaded before each call.

This technique takes more space if the variable is only referenced once, but saves space if it is referenced more than once. For example, referencing a variable twenty times takes only 67 bytes instead of the normal 140.

Unfortunately, this technique works well only when the variable is referenced in one way. Since a variable can be loaded, stored, added, etc., there really needs to be a specialized routine for each variable **for each operation.** Since several routines would be required for each variable, this would substantially reduce the space savings.

To overcome this problem, TASC uses a more sophisticated method. Rather than generating several routines for each variable, TASC generates only one routine for each variable. This single routine has a different entry point for each type of operation on the variable.

The different entry points each load a different number to indicate what operation is needed, then all use the same code to load the variable address. However, because the subroutine is now used to perform several different operations, it can no longer simply jump off to a single operation at the end. Instead, the subroutine jumps to a special library routine, and the library routine uses the operation number to dispatch and perform the correct operation.

These specialized routines are a very effective way of solving the code expansion problem. The idea of using specialized routines for each variable was introduced by the authors of TASC, and TASC is the first compiler to use this technique.

9.4.2 The RUNTIME Library

TASC uses other techniques to reduce the size of the object code. Most operations have been moved out of the object code and into subroutines in the library. This increases the size of the library, but helps to substantially reduce the size of the object code. This allows extensive use of subroutine calls in the compiled code, and produces unbeatably compact object code with only a minimal reduction in speed.

The runtime library included with TASC has a second advantage. Not only does it help produce compact object code, but it also reduces the amount of disk storage required. Rather than keeping needed routines with each program, a general purpose library is kept as a separate file. This allows all programs to use a common library, and saves each object code file from having to include some of the same routines.

With many programs on one disk, this produces a substantial space savings. One disadvantage is that the whole library is used for every program. For programs that don't use any strings, for instance, the string routines are still included. However, large programs typically use most of the routines in the library, and small programs have enough memory left over so that including the extra routines does not present a problem. The library also fits well below the first HIRES screen, providing a way to effectively utilize space that might otherwise be wasted.

10. Error Messages and Debugging

This chapter explains the error messages that can occur either at compiletime or runtime.

10.1 Compiletime Error Messages

TASC uses two types of error messages; warnings and fatal errors. Fatal errors indicate problems that prevent successful compilation. Warnings simply indicate statements that are ignored by the compiler, such as unsupported Applesoft features or unexecutable code.

Warnings that indicate unexecutable code are usually caused by statements following a GOTO or RETURN on the same program line. Warnings do not prevent an object file from being created, but no code is generated for the flagged statements. Unsupported statements are simply ignored, and no code is generated for them. RESUME is ignored unless the RESUME compilation option is turned on.

Fatal errors provide both a message and an error token. The error pointer, !ERR!, appears in the incorrect statement at the point where the error was recognized. Fatal errors cause the incomplete object file to be deleted. Compilation continues only so that any other errors can be detected; code generation does not continue. The list that follows describes the fatal errors and their causes:

DECLARATION	INTEGER or COMMON declarations out of sequence or not at beginning of program. USECOMMON and DEFCOMMON both declared in a single program. Variable declared as COMMON more than once.
INCOMPLETE	Incomplete expression. Missing right parenthesis in expression.
OPERAND	Illegal operand in expression. Arithmetic constant too large.

REDEFINED	Function defined more than once. Specified array dimensions different than the first dimensions specified.
SUBSCRIPT	First subscript missing. Dimension not an integer constant. Dimension negative or greater than 32767. More than 88 subscripts. Different number of subscripts than in first usage.
SYMBOL TABLE FULL	Compiler out of symbol table space. See section 5.3, Compiling Long Programs.
SYNTAX	Missing or added character or item. Line number greater than 65534.
TOO COMPLEX	Expression too complex. IF/THEN nesting too deep.
TOO LONG	Input line longer than 240 characters. Object code or variables for compiled program extend past 48K. See section 5.3, Compiling Long Programs.
TYPE MISMATCH	Numeric expression where string was expected, or vice versa. String expression in IF/THEN.

Undefined line numbers or functions produce fatal errors at the beginning of PASS2. The line number given in the error message is the **last** reference to the function or line. Any other references must be corrected as well.

The compiler expects a source file that has been tokenized and has had spaces removed by the interpreter; the compiler does not allow extra spaces. Additional spaces will cause syntax errors during compilation. If a file does have added spaces in it, the spaces can be removed by LISTing the program into a text file, then EXECing the text file back into memory. See the Apple DOS Manual under EXEC for more information.

10.2 Runtime Error Messages

With the exception of the "?TYPE MISMATCH" error, the error messages produced by a running compiled program are identical to those provided by the interpreter. The type mismatch error in its normal sense never occurs at runtime, since type checking is performed during compilation. The type mismatch error is used instead to indicate mismatched COMMON blocks. See the section on COMMON in Chapter 8, Language Enhancements, for more information.

Since the compiled code is a machine language program, it does not print line numbers in error messages. Whenever it can, however, it provides an object code address. This object code address can be matched with the corresponding line in the Applesoft source program by using the line number to object code address reference offered at the end of PASS2. If a program has errors, it should be debugged again with the interpreter.

Some errors that occur at runtime cannot include an object code address. These errors are printed with an address of 0. Using the ONERR/Debug option makes it possible for the compiler to always include an object code address, but including this option produces a longer and slower object file. For this reason, program development and debugging should be carried out using the interpreter whenever possible.

Runtime errors cause a compiled program to halt without correctly re-initializing the interpreter. Typing NEW after a runtime error ensures that the pointers and locations used by the interpreter are set up correctly.

10.3 Sources of Common Problems

TASC is exceptionally compatible with the interpreter, but there are still some problems that may occur with compiled programs. Chapter 7, A Compiler/Interpreter Language Comparison, explains most of the language differences between compiled and interpreted programs. This section is provided as a trouble-shooting guide for compiled code that jumps into the monitor or acts strangely.

10.3.1 The Applesoft Interpreter

Compiled programs can only be executed when the Applesoft interpreter is available at its normal location in memory. Attempting to execute a compiled program without the Applesoft interpreter prevents the compiled code from running. Attempting to execute a compiled program from Integer BASIC rather than Applesoft produces the same problems. The Applesoft interpreter may be present in any form: ROM, RAMcard, language card, etc. Compiled code will **not** run with the old version of Applesoft that loads in as an Integer program.

10.3.2 HIRES Graphics

TASC fully supports all HIRES graphics without modification, bute the HIRES screens and shape tables often present memory conflict problems. Applesoft uses two areas of memory that correspond to the two HIRES "screens", HGR and HGR2. The area of memory used by HGR resides from 8192 to 16383 ($2000-$3FFF hex), and the area from 16384 to 24575 ($4000-$5FFF hex) is used by HGR2. These areas of memory are mapped to the screen to display the HIRES graphics.

Executing an HGR or HGR2 command writes zeroes through the appropriate area of memory, and will destroy any part of the compiled program, library, or variables that extends into the area. If part of one of these blocks is destroyed, the compiled code behaves unpredictably. In general it simply jumps into the monitor, but it may demonstrate other problems as well. Variables may be suddenly zeroed, strings may be left containing garbage, etc.

This problem is usually easy to recognize and correct. The problem occurs only with programs that use HIRES graphics, and usually occurs shortly after they attempt an HGR or HGR2.

Problems with the HIRES screens can be prevented by examining the statistics provided at the end of compilation. The addresses included indicate where the program, library, and variables reside. If the program uses HIRES graphics, check the addresses to insure that they do not conflict with the addresses given above for the appropriate HIRES pages. If there is a conflict, the program must be recompiled using the alternate memory allocation methods discussed in Chapter 5, Compilation.

Shape tables used by HIRES graphics are often the cause of more subtle problems. Shape tables must be BLOADed or POKEd into memory just like machine language programs, and often present the same memory conflict problems. The shape table may reside in the same place that the compiled code is expected to lie.

In fact, shape tables for interpreted programs tend to be stored exactly where programs compiled to fit around the HIRES pages reside. The interpreted program normally fits below the HIRES page, so the shape table is often kept just above the page. However, this is exactly where the program resides if it is compiled using the HGR1 and HGR2 memory allocation options. When shape tables are used, their location can usually be determined by looking at the addresses specified in the POKEs that put them in memory. If there is a conflict, it is usually most simple to relocate the shape table. However, the program can also be compiled at a different address by using the information in Chapter 5.

Normal LORES graphics do not present a problem. The memory mapped to the screen by LORES graphics is the same as the memory mapped in normal text mode, and this area is out of the way of both compiled and interpreted programs.

10.3.3 Machine Language Programs

Machine language programs used with Applesoft often depend on variables or program lines residing in a specific place. Since compilation totally changes the internal representation of the program, some machine language programs simply do not work with compiled code.

When a machine language program does not work because it depends on characteristics of the interpreted program, the machine language routine must usually be rewritten. However, some machine language programs create problems only because they present memory allocation conflicts.

Machine language programs are usually written and assembled to reside at a certain address. The Applesoft program normally puts the machine language program in memory by BLOADing or POKEing it. CALLs, POKEs, PEEKs, and BLOADs often indicate the use of a machine language program.

Some machine language programs are also tacked onto the end of Applesoft programs, so that the machine language routine is loaded in with the Applesoft file. These machine language programs are harder to detect, and make successful compilation difficult. "PENNY ARCADE" on the Apple demonstration disk is an example of this type of program. The original author is usually the only one who can easily straighten out these programs.

Machine language programs are normally CALLed from the Applesoft program. The addresses specified in the CALLs or POKEs are usually a good indication of whether or not the machine language programs will cause problems. Most routines are written to reside in page three, which is unused by both interpreted and compiled programs. Parts of page three are used by DOS, but the majority of it is free for use. Page three occupies locations 768-1023 ($300-3FF hex).

Routines located in page three usually do not cause problems. Since page three is not used by the compiled code, the machine language program does not present a memory conflict. However, some rou-

tines still present compatibility problems. CALLs in ONERR GOTO routines usually indicate a special Applesoft routine that is used to clear up problems with ONERR GOTO. See Chapter 7, A Compiler/Interpreter Language Comparison, for more information about the ONERR machine language routine.

10.3.4 Self-Modifying Programs

Some interpreted programs achieve special effects by modifying themselves as they run. "PHONE LIST" on the Apple demonstration disk is an example of this odd technique. The interpreted version of PHONE LIST POKEs the entered names and addresses into DATA statements inside itself, saving the data by modifying itself as it runs. Other programs "hide" parts of themselves to speed execution. These programs do not work properly when compiled. The only way to compile these programs is to re-write them using more straightforward methods.

Appendix A
Moving Binary Files with the ADR Utility

A.1 Binary Files

TASC compiles Applesoft files to produce machine language files. Since the machine language files are not Applesoft programs, their format on disk is different from an Applesoft program. This section describes how to load and save the machine language files.

DOS currently includes three file types: Applesoft, Text, and Binary. The type of a file is indicated by a single letter in the CATALOG. File types are indicated by an "A", "T", or "B", which represent Applesoft, Text, and Binary files. The input files to TASC are Applesoft programs, so they are indicated by an "A" in the catalog. The machine language files produced are stored in binary format, and they are indicated by a "B" in the catalog.

A.2 Saving and Loading Binary Files

The usual LOAD <filename>, SAVE <filename>, and RUN <filename> DOS commands work with Applesoft files, but they cannot be used with binary files. DOS provides a corresponding set of commands for binary files — BLOAD, BSAVE, and BRUN. The "B" prefix to the commands denotes a binary file. The commands function much the same as the corresponding commands for Applesoft files, but there are some differences.

DOS SAVEs Applesoft programs by using information from the Applesoft interpreter. The interpreter provides the information about the beginning and length of the program to be saved, and DOS writes the program to disk. DOS saves the length information with the file so that the program can be LOADed back into memory later. The user does not have to worry about telling DOS where the program starts or how long the program is: the Applesoft interpreter provides DOS with all the necessary information.

The Applesoft interpreter cannot provide the information necessary to load and save machine language programs. The interpreter keeps track of where the current Applesoft program resides, but it does not retain information about machine language programs. Therefore, the user must specify additional information to BLOAD and BSAVE machine language programs.

The BSAVE command is similar to the SAVE command for Applesoft programs. BSAVE saves a portion of memory to disk in binary format. Compiled programs are treated like any other binary data in memory. Since the Applesoft interpreter can no longer provide the beginning and length information necessary, the user must specify the starting address and length of the memory to be BSAVEd. The normal syntax for the BSAVE command is:

BSAVE <filename>, A <address>, L <length>

The two letters "A" and "L" precede the numbers that indicate the starting address and length of the memory to be saved. The numbers can be specified in either hexadecimal or decimal format. Hexadecimal numbers are base sixteen, and decimal numbers are the normal base ten. If hexadecimal numbers are used, they must be preceded by a dollar sign "$". Decimal numbers are used without any special characters. The usual slot, drive, and volume parameters can also be used with BSAVE, BLOAD and BRUN.

BLOAD and BRUN are similar to the Applesoft file commands LOAD and RUN. LOAD for Applesoft programs simply moves the program into memory; RUN LOADs the program, then RUNs it. Similarly, BLOAD loads a section of memory from a binary disk file; BRUN BLOADs the section, then CALLs the beginning of the section to execute it. Since the binary files stored by the compiler are machine language programs, BLOAD will load a compiled program; BRUN BLOADs the program and runs it. As explained in Chapter 6, Executing a Compiled Program, RUNTIME must be in memory before a compiled program can be BRUN.

BLOAD normally loads the contents of the disk file back into the same area of memory from which the file was BSAVEd. For instance, BLOADing a machine language program that was BSAVEd starting from location 4000 loads the program back in at location 4000. How-

ever, it is also possible to BLOAD a disk file to a different location in memory. The "A" parameter can be used to specify a different starting address for the file. Typing "BLOAD <filename>, A 6000" always loads the binary file into memory starting at location 6000.

The "A" parameter cannot be used to load and run an object file at an address different from the one at which it was compiled. Compiled programs will not run correctly if they are run at a different address.

The "A" parameter with BLOAD is normally used only to BLOAD the RUNTIME library at an address different from its default. The default address for the library is 2051 ($803 hex), and because the library was BSAVEd to disk from that address, it normally BLOADs at that address. Specifying the "A" parameter allows the library to be loaded at an address different from its default. The "A" parameter is also accepted in the BRUN command, but as just mentioned, compiled programs cannot be BRUN at an address different from their normal location. Neither BLOAD nor BRUN can include the "L" parameter, since the whole disk file is always loaded. See the DOS manual under "Binary Files" for more information about binary file commands.

A.3 The ADR Utility

Since the address and length of the memory range must be specified in the BSAVE command, moving compiled programs from disk to disk is not as simple as moving Applesoft programs. The compiled program can still be BLOADed without specifying any extra information, but it cannot be BSAVEd without knowing its beginning address and length. The ADR utility is included on the TASC disk to make finding the required information simple.

DOS keeps the beginning and length of the most recently BLOADed or BRUN file in special locations. The ADR utility simply looks at the contents of these locations and prints the beginning and length of the most recently loaded file. ADR is a text file, so it should be executed by typing "EXEC ADR". ADR does not affect any program or file in memory; it simply EXECutes a PRINT statement to

provide the needed information. Since the PRINT statement is only understood by the Applesoft interpreter, ADR must be EXECed from the Applesoft interpreter. ADR will not work from the monitor.

ADR prints out the decimal beginning address and length of the most recently loaded file. The numbers printed should be used with the "A" and "L" parameters to BSAVE the machine language program to disk. The normal sequence for moving a program from one disk to another is:

```
BLOAD  <filename>
EXEC  ADR
BSAVE  <filename>,A<address>,L<length>
```

The address and length for the BSAVE are found by EXECing ADR and are simply included in the BSAVE preceded by "A" and "L". The same procedure can be used to move the other binary files on the TASC disk — RUNTIME, PASS0, PASS1, and PASS2.

The program CREATE ADR is included so that the ADR file can be used on other disks. Since ADR is a text file, it cannot be LOADed and SAVEd or BLOADed and BSAVEd to transfer it to another disk. Instead, the CREATE ADR program must be used to write a copy of the text file onto the new disk.

The procedure for transferring the ADR file to a new disk is simple:

1. Load the CREATE ADR program from the TASC disk,
2. Remove the TASC disk,
3. Insert the disk that the new copy should be created on, and
4. Type RUN.

The CREATE ADR program opens up a text file called "ADR" on the disk, writes the PRINT commands into it, then closes the file and stops. The new ADR file will be identical to the ADR file on the compiler disk. See the DOS manual under "EXEC" for more information on EXEC text files.

Appendix B
Copying TASC and Converting to DOS 3.3

TASC is provided in DOS 3.2 format. Five files are actually used by the compiler; TASC, RUNTIME, PASS0, PASS1, and PASS2. TASC is a short Applesoft program, and RUNTIME, PASS0, PASS1, and PASS2 are binary files. See Appendix A, Moving Binary Files with the ADR Utility, for information about how to transfer these files to another disk. The TASC file is an Applesoft program and can be moved by using LOAD and SAVE. The whole disk can also be backed up by using any standard disk duplication utility.

TASC was designed to be compatible with both DOS 3.2 and 3.3. All the files included on the TASC disk can be updated to DOS 3.3 without modification. The 3.3 Master disk includes a machine language program called "MUFFIN" that can be used to convert the 3.2 files to 3.3. See the DOS 3.3 manual for more information on using MUFFIN.

Appendix C
Creating a Turnkey Disk

It is quite simple to make a turnkey disk that runs a compiled program when the disk is booted. The Applesoft program given in this section BLOADs the RUNTIME library and BRUNs the desired file. Typing this program in as the HELLO program on a disk allows the compiled object code to be executed when the disk is booted. See the Apple DOS Manual for more information on creating turnkey disks.

The following program loads and executes the binary file "PROGRAM.OBJ". To use it, simply change "PROGRAM.OBJ" to the name of the actual program.

```
10 PRINT CHR$(4) + "BLOAD RUNTIME" + CHR$(13) +
    CHR$(4) + "BRUN PROGRAM.OBJ"
```

CHR$(4) is the disk character <CTRL-D>, and CHR$(13) gives a <RETURN>. The PRINT statement executes two disk commands — a BLOAD and a BRUN. The <RETURN> is needed to separate the two commands.

The Applesoft program itself is usually destroyed by the BLOADed RUNTIME, so both the BLOAD and BRUN must be in one PRINT statement. If they were in separate PRINTs, the second PRINT would be destroyed by the BLOAD before it could be executed. This is also why concatenation (+) is used to join the strings. If the strings are not actually concatenated, each substring is output separately, and the same problem occurs.

Appendix D
Notes on Applesoft

Since TASC is designed to implement the features of Applesoft as closely as possible, there are very few differences between the interpreter and the compiler. The differences that do exist are explained in Chapter 7, A Compiler/Interpreter Language Comparison. This appendix is included as a further explanation of some of the features and peculiarities of Applesoft, and gives some information about Applesoft statements that is not included in the Applesoft II BASIC Programming Reference Manual.

Information is included on the following:

1. TAB and SPC in PRINT statements,
2. Re-entry of parameters after an error in INPUT,
3. Screen wrap-around with DRAW and XDRAW,
4. The ONERR GOTO statement, and
5. FOR/NEXT statements.

D.1 TAB and SPC

The operation of TAB and SPC is different than might be expected. When used as the last item in a PRINT statement, TAB and SPC act as if they are followed by a semicolon, and suppress the printing of a carriage return.

For example, the following program lines are equivalent:

```
PRINT  "SAME" TAB(10) : PRINT "LINE"
PRINT  "SAME" TAB(10); : PRINT "LINE"
PRINT  "SAME" TAB(10) "LINE"
```

All three forms PRINT:

```
SAME      LINE
```

D.2 The INPUT Statement

The description of the INPUT statement in the Applesoft manual explains the "?REENTER" message in detail. However, remember that when the "?REENTER" message is displayed, the **entire** INPUT statement is re-executed. Consider the following response to the statement "INPUT A,B,C":

```
2,3,"NOT A NUMBER"
```

The "?REENTER" message is printed because the string "NOT A NUMBER" cannot be assigned to the numeric variable C. However, Applesoft is requesting the reentry of all three inputs, starting with the value for A. It is not just expecting another single input for C.

D.3 DRAW and XDRAW

DRAW and XDRAW are HIRES commands for plotting shapes. DRAW and XDRAW require legal X,Y coordinates to specify the starting point for plotting the shape. However, the shape is not necessarily a single point, so it can occupy space on either side of the

specified point. As long as the starting point is on the screen, plotting a shape near the edge of the screen does not give an "?ILLEGAL QUANTITY ERROR".

If the shape extends past the edge of the screen, the Applesoft DRAW routines wrap the off-screen portion around to the other side. This is not a particular problem, but it can produce abnormal displays.

D.4 ONERR GOTO

ONERR GOTO has a little known problem that causes the interpreter to ignore any statements following an ONERR GOTO statement in a given program line.

The statement PRINT "AND AFTER" in line 10 of the following program is never executed:

```
10 PRINT "BEFORE": ONERR GOTO 30: PRINT "AND
   AFTER"
20 STOP
30 PRINT "ERROR"
```

Since the ONERR GOTO statement does not necessarily transfer control when it is executed, placing statements after an ONERR GOTO is quite reasonable. Unfortunately, however, the interpreter **always** ignores them. To avoid any confusion, the compiler handles ONERR GOTO in the same way as the interpreter.

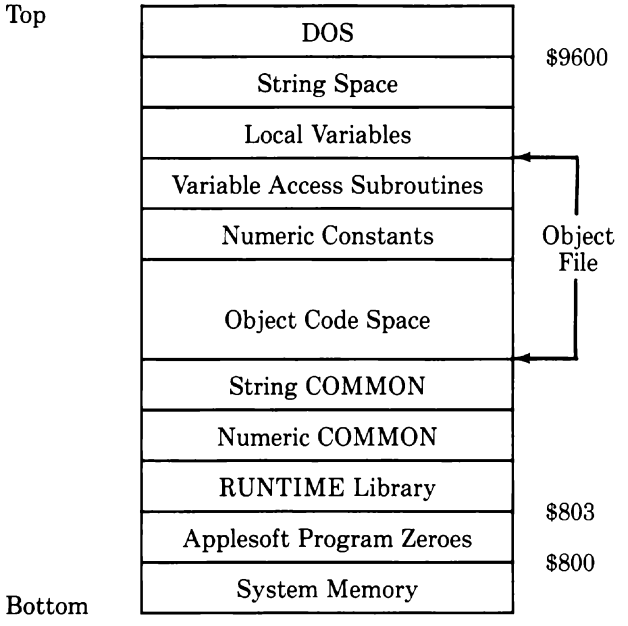
D.5 FOR/NEXT

The interpreter's implementation of FOR/NEXT loops includes many special features that remove many of the restrictions normally placed on FOR/NEXT loop nesting. TASC fully supports all features of Applesoft FOR/NEXT loops.

Appendix E
Runtime Memory Map

The following diagram shows the default memory configuration for a compiled program. The default can be modified by explicitly specifying the memory addresses at the beginning of compilation. See Chapter 5, Compilation, for more information.

String variables point into a string area that contains the actual string values. The string values grow downward from the top of memory toward the bottom of the available space. When the strings fill the available memory, the compiler forces garbage collection and frees up any unused space. If not enough space is available after garbage collection to store the next string, the compiled code gives an ?OUT OF MEMORY error.



Appendix F
Zero Page Usage

Compiled programs use routines from the Applesoft interpreter and the RUNTIME library. Both the interpreter routines and the RUNTIME library make extensive use of a portion of memory called the "zero-page". The zero page resides from $00 to $FF (decimal 0-255).

Both page zero and page three ($300-$3FF, or decimal 768-1023) are also often used by short machine language programs. Compiled code changes the Ampersand vector at $3F5 to allow re-execution of the compiled program, but does not otherwise modify page three.

Zero page usage is confined to the locations that are already used by the Applesoft interpreter. This should eliminate any zero-page conflicts with machine language routines designed to be used with Applesoft.

Compiler Zero Page Usage

Hex address	Usage
0D-0E	Temporaries
10	Temporary
12-13	Address of first DATA string
14-15	Highest location used by library, program, or variables
16	Temporary
50-51	Address temporary
55-56	Temporary
58-5A	JMP to library routine that floats integer accumulator
5B-5D	JMP to code currently handling ONERR
62-66	Temporaries
67-68	Applesoft beginning of program pointer
69-6A	Beginning of common block — 1
6B-6C	End of numeric common
6D-6E	End of string common
6F-70	Bottom of strings — 1
71	Input buffer pointer
73-74	Applesoft HIMEM
75-76	Address of object code being executed
77-7A	Temporaries
7B-7C	Beginning of local variables — 1
7D-7E	End of local numeric variables
7F-80	End of local string variables
83-84	Temporary
8A-8F	Temporaries
9E-A3	Integer accumulators
AD	Temporary
AF-B0	Address of routine that pops FOR entries from the stack
B1-C8	Applesoft CHRGET, modified, but still functions normally
D9	Temporary
DA-DB	ONERR handling
DC-DD	Temporary
DE	Applesoft error number for error
DF	ONERR handling
F4-F5	ONERR handling
F6-F7	Address of current DATA statement
F8	ONERR handling

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